APPENDIX G
PRELIMINARY OUTLINE FOR
COMPREHENSIVE MONITORING AND EVALUATION PROGRAM

TABLE OF CONTENTS

G.1 INTRODUCTION: KEY CHALLENGES FOR MONITORING AND EVALUATION G-1

G.2 HIERARCHICAL SYSTEM OF MONITORING G-3

TABLES

G-1 Outline of proposed monitoring and evaluation sampling design G-4

This page is intentionally left blank.

G.1 INTRODUCTION: KEY CHALLENGES FOR MONITORING AND EVALUATION

Monitoring and evaluation[1] are not merely the periodic collection of data. Rather, properly designed monitoring programs will provide the necessary data for resolving a wide range of uncertainties, including determining population status, establishing causal relationships between habitat (or other) attributes and population response, and assessing the effectiveness of management actions.

To be most useful, a monitoring and evaluation program, like any other scientific endeavor, should be question-driven. The five main areas and questions that the Columbia Basin monitoring and evaluation program must address are as follows:

- **Population status monitoring.** What areas do juvenile salmonids and spawning adults occupy? What is the status of the population (i.e., abundance, trend and variation)? Does that status change through time?
- **Environmental status monitoring.** What is the status of environmental attributes, including non-native species, potentially affecting salmonid populations? Does it change through time? Are there associations between environmental attributes and salmonid population status?
- **Effectiveness monitoring.** Are management actions having the intended effects on the aquatic system, and what is the response of salmonid populations to those effects?
- **Quality of regional databases.** How accurate and complete are currently available databases that represent habitat quality throughout the basin?
- **Compliance monitoring.** Have management actions been properly implemented and maintained?

Economies can be achieved by designing a monitoring and evaluation program so that different sampling sites and efforts intersect other sampling sites and efforts in a way that serves multiple needs. Outlined below is a hierarchy of three sampling tiers that is designed to fulfill these several purposes efficiently. Sampling activities in each tier are conducted at different spatial scales, consider different levels of biological detail, and assess different types of habitat attributes.

Monitoring is a scientific activity. As such, it will evolve as salmon science progresses. However, the backbone of any monitoring program should be solid enough to remain in place for decades to come—with the changes that occur taking the form of additional measurements or supplementary efforts.

[1]This preliminary outline for a comprehensive monitoring and evaluation program was formulated In November 2000 by the Northwest Fisheries Science Center (NWFSC), National Marine Fisheries Service (NMFS). It will be fully developed through a collaborative effort of NWFSC, regional agencies, and scientists.

This page intentionally left blank.

G.2 HIERARCHICAL SYSTEM OF MONITORING

To meet the challenge of monitoring and evaluation, NMFS intends to deploy a monitoring program that involves three tiers of sampling, in ascending detail, in both freshwater systems and the estuary. Table G-1 summarizes the entire monitoring scheme. For each of these two areas (monitoring and evaluation), the purpose of each tier is described first, then the data that will be collected at each tier are described in general terms. Following this, specific details are provided for environmental status and compliance monitoring programs that complete the necessary data collection. Finally, the further analyses and activities that must be completed before a detailed monitoring program can be established are briefly outlined.

Tier 1. Tier 1 sampling is the broadest of the sampling levels, comprising the greatest number of sites, sampled at the lowest frequency. It is designed to give the broadest picture of salmonid population status and the condition of the habitats in which they are found. Tier 1 data will contribute to population status monitoring, environmental status monitoring, the quality of databases, and compliance monitoring. They have the potential to contribute to effectiveness monitoring in those situations where the expected population response is range expansion. Specific goals associated with this tier are 1) defining areas currently used by adults and juveniles, 2) detecting altered status of populations due to range expansion or shrinkage, 3) identifying associations between salmon presence and habitat attributes, and 4) ground-truthing regional habitat quality databases.

Freshwater Systems

a. *Fish*
   - Status of spawners and/or juveniles
   - Status of hatchery-origin spawners

b. *Habitat.* Habitat variables selected for tier 1 monitoring and database ground-truthing are either linked to annual population growth rate by preliminary statistical analyses or have not been collected, although they are important. These variables are listed below:
   - Stream temperature
   - Pesticide and heavy metal contamination (water sample)
   - Number of diversions or dams
   - Qualitative or quantitative assessment of erosion processes
   - Channel modification (including placer mining)
   - Channel morphology

Table G-1. Outline of proposed monitoring and evaluation sampling design.

	Tier 1	Tier 2	Tier 3	Landscape Imagery	Compliance Logbook
Sampling frequency	Once every 3-4 years	Annually	Frequency depends on study; minimum annually	Once every 3 years	Once every 6 months (action agency); arbitrarily to monthly (regulatory agency)
Relevant to monitoring types[1]	1,2,3,4,5	1,2,3,4,5	3,5	2	5
Goals[2]	A, B	B, C	C, D	B	
Number of sites	To cover all potentially used areas in a population	To be determined by power analyses	Minimum 3 per ESU; minimum 2 for each major management action	Entire Columbia Basin	All management actions
Data type—salmonid population	Presence/absence	Counts of juveniles and spawners	Depends on management action; hatchery spawner reproductive success	None	None
Data type—habitat	General, qualitative	Qualitative and quantitative	Quantitative, depends on management action	Landscape-level attributes	None

[1]Relevant to monitoring types: 1 = population status monitoring, 2 = environmental status monitoring, 3 = effectiveness monitoring, 4 = quality of regional databases, 5 = compliance (implementation) monitoring.

[2]Goals as follows: A = establish fish habitat use or range; B = establish associations between environmental characteristics and population status; C = estimate population growth rates or stage-specific survival rates; D = establish mechanistic links between management actions and salmon population response.

- Instream flow
- Substrate
- Riparian condition
- Land use categories in the riparian area
- Habitat types (side channels, pools, etc.)
- Status of nonindigenous fish species or dominant riparian plant species

c. *Compliance monitoring.*
- Checklist of required actions in sampling area (e.g., status of riparian fences)

Estuary

a. *Fish.*
- Status of wild juveniles
- Status of hatchery-origin juveniles

b. *Habitat.* Habitat variables selected for tier 1 monitoring in the estuary are very general and will be refined as the database of fish use of the estuary and plume increases. Preliminary tier 1 habitat variables are listed below:
- Temperature
- Salinity
- Pesticide and heavy metal contamination (water sample)
- Depth
- Turbidity
- Zooplankton concentration
- Status of nonindigenous species

c. *Compliance monitoring.*
- Checklist of otherwise unmonitored actions in sampling area

Tier 1 sites will be sampled on a 3- to 4-year rotation, with each site being sampled once in that interval. Sites will be distributed to sample the full range of habitats in the area potentially occupied by the population of interest. A seasonal component will be important, particularly for juvenile surveys, to determine habitat use and availability at different times of the year.

Tier 2 sites: The monitoring at tier 2 sites is designed to give a more detailed picture of population status, allowing, in turn, a more detailed assessment of relationships between environmental characteristics and trends in salmonid populations. Tier 2 data will form the backbone of population status monitoring, as well as environmental status monitoring. They also have the potential to contribute to both effectiveness and compliance monitoring.

Freshwater

For freshwater systems, specific goals associated with this tier are 1) defining population growth rates; 2) detecting changes in those growth rates, or changes in relative abundance in a reasonable time; and 3) identifying associations between population trends and environmental

attributes (particularly with changes in those attributes over time). Data to be collected at this tier are as follows:

a. *Fish*
   - Spawner or redd counts at spawning sites [This element will be developed in the monitoring plan to determine the most effective measure to estimate population size and minimize sampling error.]
   - Juvenile counts
   - Counts of hatchery fish at spawning sites
   - Counts at dams and weirs
   - Age of spawners (subset of sites)
b. *Habitat.* Tier 2 habitat factors will emphasize variables that may be improved by management actions and that probably will have a direct impact on salmonid survival. The following tier 2 data will be collected:
   - Aquatic insect diversity and abundance
   - Primary production
   - Abundance of nonindigenous species
c. *Compliance monitoring.*
   - Checklist of required actions in sampling area

Estuary

Specific goals associated with sampling at this tier in the estuary are 1) estimating relative smolt abundance in the estuary and survival rates during the estuarine phase, 2) detecting changes in relative abundance and survival rates between years, and 3) identifying associations between smolt abundance or survival rates and environmental attributes (particularly with changes in those attributes over time). Specific data to be collected are as follows:

a. *Fish*
   - Number of wild and hatchery-origin smolts
   - PIT-tag data from all fish caught during sampling
b. *Habitat.* The following data will also be collected:
   - Status of predator species
   - Status of nonindigenous species
c. *Compliance monitoring*
   - Checklist of required actions in sampling area

Tier 2 sites will be sampled annually. The number of adult sampling sites within each population will be determined by a power analysis that requires a 75% likelihood of detecting a 5% change in lambda over 8 years. This means that ESUs made up of populations that fluctuate widely will

require more tier 2 sites than ESUs with less variable spawner counts. Sites will be distributed probabilistically within a population, ensuring that both good and bad sites are appropriately represented. To obtain the maximum benefit from habitat data, it may be important to include some stratification (channel type, for example) in the distribution of sites.

Juvenile counts, coupled with spawner or redd counts, will ultimately provide a measure of egg-to-smolt survival. This will improve estimates of population growth rate and can serve as a baseline in other monitoring efforts (see tier 3).

The number of sites to be sampled in the estuary will also be determined by a power analysis, once sufficient data are available to conduct such an analysis.

Tier 3 sites: Tier 3 monitoring is the most detailed of the monitoring levels. The specific goals of this tier are 1) establishing mechanistic links between management actions and fish population response and 2) determining the relative fitness of hatchery fish. The information gathered at this level will address some of the most fundamental questions to be answered for effective management of anadromous salmonids. First, the relative fitness of hatchery fish must be determined before NMFS can assess the true status of populations to establish appropriate recovery goals. Second, by establishing causal and quantitative links between management actions and population responses, monitoring at this tier will contribute to NMFS' predictive ability and, therefore, to a better understanding of which actions are necessary and sufficient for population recovery.

Sampling at tier 3 sites used for effectiveness monitoring will be specific to the management action being studied. Each study must, however, assess age-specific survival appropriate to the management action. In many cases, this may involve several life stages. Sediment reduction, for instance, may affect both egg-to-fry and fry-to-smolt survival rates. Whenever possible, PIT-tags or other individual marking techniques should be used in order to follow the fates of individual fish as a function of their history. Such individually based studies are important for identifying the effects of environmental conditions that are realized at later life stages. Size or growth rates, as well as demographic rates, may be important parameters in these studies. In addition, both habitat and population response to the management action should be assessed in order to identify the factors causing any fish population responses. Finally, appropriate control sites must be paired with the treatment sites in order to establish those links unambiguously. Studies conducted under the tier 1 and 2 monitoring programs will be important for identifying the important variables by which sites should be paired. When possible, these studies should be conducted in the context of a BACI (before-after-control index) design, which allows environmental impacts, such as ocean cycles, to be filtered out. Information from other monitoring tiers (especially tier 2) will also provide important controls against which changes in tier 3 studies can be assessed.

Specific sites and management activities to be included in tier 3 monitoring will be rigorously identified. Associations of environmental condition and population status identified through tier 1 and 2 monitoring will play an important role in prioritizing activities for tier 3 evaluation. Specific sites for these actions (and for controls for those actions) should be identified, considering important environmental factors (or strata). In some instances, however, pragmatic concerns may play a role in choosing sites. For instance, historically sampled index stocks will be especially valuable contributors to the tier 3 network because their historical time series offer special opportunities for distinguishing responses to management from chance fluctuations. Or, local groups may plan and fund a management activity that provides an opportunity for detailed effectiveness monitoring.

As a general rule, at least three tier 3 studies (each necessarily comprising several sites) should be identified within each ESU. In addition, at least two studies in the Columbia River basin aimed at each major management action (e.g., alteration of grazing practices, compliance with water quality standards, road closures) must be conducted.

Monitoring Outside Three Tiers

The three-tier system appropriately addresses population status and the effectiveness of management actions. It addresses environmental status, regional database quality, and compliance monitoring only on local scales, however. Two programs in addition to the three-tier system will, therefore, provide a more thorough picture of important environmental attributes.

Landscape-level Environmental Attributes

Because much of the data compiled in regional databases, or important in assessing environmental status, are more appropriately collected at subwatershed or watershed scales, the Action Agencies shall acquire and digitize aerial or satellite imagery of the entire Columbia River basin once every 3 years. This will allow a more detailed assessment of land use and land cover variables than is currently available for the region. This assessment, in turn, will allow the association of potentially important watershed-level characteristics with salmon population status. In addition, the repeated assessment of the variables through time will allow changes in environmental characteristics to be associated with changes in salmonid population status. These data will have value for resource and wildlife management well beyond listed salmon species.

Compliance Monitoring Logbooks

Compliance monitoring is necessary to determine how well management actions are implemented. While the question of proper implementation might appear trivial, this component of a monitoring program is very important for two reasons. From a regulatory perspective,

compliance monitoring is necessary to ensure that agencies and individuals responsible for mitigation or restoration activities, in fact, complete their responsibilities. From a biological perspective, we must know how well a management action is implemented. If salmon do not respond, NMFS can then distinguish between management that does not work and management that was not implemented.

Some compliance monitoring can be conducted during the three-tier system, as described above. However, not all sites will be checked during this program at the appropriate frequency. For the major management actions, compliance monitoring will be part of the tier 3 monitoring sites designed to also quantify fish responses. There will be many small management actions (involving local habitat or stream improvements) that cannot, however, be associated with detailed tier-3 sites. For these many small management actions, the agency or party conducting each action will be responsible for keeping a log book of implementation, which is entered into a web-based data archive monthly. NMFS will send out field staff on a random basis to check on the log books and validate their entries.

Logistics, Implementation, and Coordination

Refining this framework is a large task. A number of groups, most notably the Forest Service's Pacific Northwest Forest Science Laboratory, EPA, and the Oregon Coastal Salmon Restoration Initiative, have developed scientifically rigorous monitoring protocols for aquatic systems. This effort should be coordinated with those efforts and draw on these previously developed systems. NWFSC will work in conjunction with these groups and other regional agencies to refine the proposed monitoring scheme, to evaluate formally the necessary temporal and spatial replication, to identify specific localities at which the monitoring program will take place, and to develop data collection protocols. Collaboration will be especially important for identifying novel variables (such as stream invertebrates, riparian productivity, or nonindigenous species) for consideration as monitored factors. Collaboration is also necessary for the error rate in all databases to be estimated and documented.

Implementing this ambitious monitoring program will require an extraordinary degree of coordination among an enormous number of regional management agencies. Population status data are fundamental not only to risk assessment, but also to determining mechanisms of population regulation. Local agencies will necessarily play an important role in acquiring and processing these data. Environmental condition data are important both for identifying patterns between salmonid productivity and natural or anthropogenic factors and in providing the important “before” component of a BACI experiment. Some of these data will probably be collected during subbasin assessment programs. Additional coordination will be important to ensure that the full complement of environmental factors are assessed during these efforts and that ongoing data are collected as needed. Monitoring aimed at determining mechanistic cause-

and-effect relationships between environmental conditions or management actions and population responses will be conducted on a case-by-case basis, depending on the scale of the action. In these cases, agencies implementing actions and the monitoring design team may coordinate with groups or local agencies with specific expertise to apply appropriate data-collection protocols.

Because this effort will be conducted on such a large scale, it will be imperative that all data collection and reporting be conducted in a manner that allows the data to be used not only for scientific support of management actions, but also to address more basic or theoretical issues that have the potential to inform management decisions. In particular, standards for data must encompass data collection, reporting, and accessibility.